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CONTENTS

CHAPTER ONE	Cellulose Dopes and Finishes
CHAPTER TWO	Butyrate Dopes
CHAPTER THREE	Fuelproofers
CHAPTER FOUR	Plastic Enamels and Paints
CHAPTER FIVE	Films
CHAPTER SIX	Epoxy Resin Finishes
CHAPTER SEVEN	Covering and Finishing Weights (Aircraft)
CHAPTER EIGHT	Metal Finishes
CHAPTER NINE	Finishing Wood
CHAPTER TEN	Finishing Expanded Polystyrene Covering and Finishing Schedules.

CHAPTER ONE

CELLULOSE DOPES AND FINISHES

Cellulose dopes are the conventional form of 'proofing' and finish for fabric covered aircraft, whether full size or models (where the fabric may be tissue, silk or nylon). They are also effective as a sealer coat for plain balsa surfaces.

Cellulose dopes have evolved from simple cellulose-solvent solutions into rather more complex formulations offering a wider range of characteristics. There are two basic types - cellulose acetate and cellulose nitrate solutions. Acetate dopes have little or no shrinking power, tend to have less 'filling' capacity, but are more waterproof. Nitrate dopes can have high shrinking power and are generally regarded as more durable. These differences are not important as modern cellulose dopes may contain resin additives, and various types of solvents and thinners modifying the basic characteristics of the cellulose material. It is therefore, more useful to classify cellulose dopes under more general headings, viz -

- (i) Clear model dope
- (ii) Clear tautening dope
- (iii) Glider dope
- (iv) Banana oil
- (v) Coloured dopes
- (vi) Cellulose enamels.

Clear model dope

Starting with clear model dope, this is basically a well thinned cellulose solution (i.e. with a high proportion of thinners) with very limited tautening effect. It also has relatively low 'filling' power and low resistance to water. It is a satis-

factory finish for jap tissue, which can readily be tautened by water spraying, and not likely to warp fragile structures on drying. On the other hand it allows the covering to slacken off readily in a damp atmosphere because of its relatively low 'proofing' ability.

Clear tautening dopes

Clear tautening dopes come in various strengths. A strong dope has high tautening powers - sufficient to warp non-rigid frames, unless suitable precautions are taken. At the same time, it resists slackening off in damp. The strength can be reduced by increasing the proportion of thinners and proprietary clear dopes, therefore, have different degrees of tautening power, depending primarily on the proportion of thinners used in their make up. Equally, a dope which is too 'strong' for a particular job can have its strength reduced by adding thinners.

It is necessary to use a tautening dope on tissues which do not respond to water-shrinking (e.g. 'wet strength' tissues and Modelspan); and on silk or nylon coverings which can only be tautened by the application of a tautening dope. In this case a strong tautening dope is essential, at least for the first coat or two. The application of weaker dopes will only cause slackening and wrinkling to develop in such coverings.

Glider dope

Glider dope is a full strength 'full size' aircraft clear dope, possessing high tautening powers. It was, at one time, the only reliable 'strong' clear dope available for aero modelling, and too strong to be used on tissue coverings without reducing with thinners (although ideal for silk and nylon in unthinned form). It has largely been replaced by the development of strong clear tautening dopes developed specially for model use giving comparable tautening. These dopes also have the advantage of being water-clear rather than the yellowish colour associated with original glider dope.

As a general rule, the stronger the dope the better its 'proofing' qualities, i.e. the more resistant it is to slackening of the covering in damp conditions. This applies particularly

in the case of tissue coverings. The difficulty then lies in utilising such a strong dope, for an initial coating at least, without warping relatively fragile structures, such as lightweight wings and tail surfaces. An almost ideal treatment would be to use an initial coat or two of really strong dope, followed by further coats of thinner dope (not necessarily tautening) to build up a water resistance surface. There are necessary limits to what can be achieved, both from the point of view of added weight and the fact that the greater the number of coats of dope applied to a paper or fabric material, the more that material tends to develop brittleness with age.

Banana oil

Banana oil rates as a 'proofing' coat. It has no tautening properties, but better water-resistant qualities than ordinary clear dopes. In fact it is really just another form of non-tautening clear dope, perhaps with some resin added. 'Banana oil' as such does not exist as a recognised cellulose dope, but is merely a popular name for a 'waterproofing' or acetate-base dope. It was so called because the original dope of this kind smelt more like bananas than pear drops or ordinary dopes. Modern waterproofing dopes of this kind are more accurately called waterproofing dopes or clear cellulose varnishes. They are usually based on cellulose acetate, because of the better (but not complete) water resistance of this material. Some, also known as paper varnishes, are heavily loaded with resins to produce a high gloss finish.

Apart from the question of selecting or arriving at the required tautening power for a particular application, modern clear dopes are essentially troublefree in use and application. Some clear dopes, particularly glider dopes, were prone to 'blushing' or turning white whilst drying, particularly in damp atmospheres. This can be eliminated by incorporating a proportion of anti-chill thinners in the dope which retards and controls the rate of drying, preventing blushing occurring. Should blush patches appear on a clear doped surface, the whiteness can usually be removed by brushing in anti-chill

thinners, or even ordinary thinners, before the dope has fully set (or as soon as possible after blushing appears).

An important point not commonly appreciated is that whilst tautening dopes become surface dry in a matter of minutes after application, and have apparently dried out completely in a matter of a few hours, contraction of the dope film will tend to continue for many days. The established method of pinning down wings and tailplane and leaving them overnight to prevent warping is thus not a complete safeguard. It will only eliminate major warps which may occur under the initial and main tautening action of the dope. Further slight warps may well appear at a later stage which is why an ageing period of one to two weeks with lightweight wings and tailplanes is often recommended before any new contest model is regarded as ready for final trimming. This is not necessary with heavier wing structures, or anti-warp structures which are quite capable of resisting this secondary tautening action of cellulose dopes.

Coloured dopes

Coloured dopes are almost invariably non-tautening. The cellulose solution is merely a carrier for the fillers and pigments. Powdered fillers are incorporated to thicken the solution and give it 'body'. It is these fillers which considerably increase the weight of the dope, compared with clear dope, since they are deposited in the dope film. Pigments are added to give colour, these also usually being in the form of another powder, adding further weight. A higher proportion of solids content is usually necessary to give consistent, opaque colours in lighter colours, which is why lighter coloured dopes are usually heavier than darker colours. Aluminium is the exception, for in this case only a minimum of fillers is required (or they may be omitted entirely) and the resulting solids content is relatively low because of the good covering power of aluminium powder.

Coloured dopes may also include synthetic resins to impart gloss, producing the so-called gloss dopes. A coloured dope without resin will have a semi-gloss appearance, the degree

of gloss depending largely on the number of coats applied. Further additives are needed to kill the natural semi-gloss of cellulose to produce a true matt finish cellulose dope, although the degree of gloss can also be controlled to some extent by the type of filler used.

Cellulose enamels

Cellulose enamels are colour dopes with a high resin content, the resin being specially selected for its high gloss qualities and uniform flow properties. Since these are intended for 'quality' finishes, more attention is given to flow properties to ensure even coverage when brushed or sprayed. Most modern high gloss dopes, however, also have good flow properties and there is often little or no difference between them and cellulose enamels.

Opalescent or 'metallic' finishes are readily produced by mixing aluminium powder or aluminium dope with coloured dopes. It is important that only a cellulose aluminium dope should be mixed with a cellulose coloured dope. An oil-based aluminium paint or enamel would not be compatible.

Opalescent coloured dope finishes were at one time much favoured for power model aircraft finishes, both for appearance and the fact that an aluminium-colour dope provides better coverage and lower weight than a plain colour.

Where weight saving is important, coloured tissue or coloured nylon is normally used, finished or 'proofed' with clear dope. The resulting colour will tend to be translucent rather than 'solid' and opaque. The colour can be greatly improved, without adding much weight, by using a small proportion of coloured dope mixed with clear dope for the final coatings - e.g. after the first one or two 'tautening' coats, for which clear dope only should be used. Such thin coloured dope coatings should be applied by spray, if possible, in preference to brushing on.

Cellulose finishes are reasonably water-resistant, but by no means waterproof. Water can readily penetrate cellulose

films during prolonged immersion. This is not necessarily a problem with model boat finishes, but precludes cellulose as a finish for full size marine work.

Cellulose finishes are generally, if not completely, resistant to petrol and mineral oils (but not castor oil). They are not resistant to glow fuels, however, and so for glow engine powered models, need a final protective coating. This is usually an overall finish coating of fuelproofers (see Chapter 3). Fuelproofers are also usually good water-resistant coatings and so may also be applied to advantage on diesel engine powered models.

CHAPTER TWO

BUTYRATE DOPES

Cellulose acetate butyrate (CAB) is somewhat similar to cellulose acetate, but with enhanced properties - particularly in its resistance to attack by solvents. It can be used as an alternative to normal cellulose (acetate or nitrate) to produce both clear and coloured dopes. It retains some of the basic properties of cellulose acetate dopes - good waterproofing qualities, and low shrinkage - but is more resistant to all fuels and oils, including glow fuels. It can, therefore, be used as a 'fuelproof' finish in place of ordinary cellulose dopes, without the need for a final coat of fuelproofers. It was originally developed and widely used in America as a fuelproof dope. Butyrate dopes, as they are generally called, have only been produced in this country comparatively recently, and even then demand for them has not been very high.

One of the reasons is that butyrate dopes can vary considerably in performance, depending on their actual formulation. Not all butyrate dopes are fully fuelproof, and some commercial attempts to produce clear butyrate dope as a fuelproofers have been singularly unsuccessful. Also a butyrate film is more prone to fail by lack of adhesion or crazing than conventional cellulose dopes, unless such tendencies are completely inhibited in the formulation.

There is also the problem that butyrate dopes are not generally compatible with ordinary cellulose dopes. That is, they may not adhere properly if applied over an ordinary cellulose nitrate tautening dope, which may well be necessary to achieve the desired tautening because of the relatively low 'strength' of a clear butyrate dope. This is not an invariable rule. Some coloured butyrate dopes can be applied quite suc-

cessfully over an initial coat of cellulose nitrate dope. In other cases, sufficient tautening may be obtained with a clear butyrate dope to use an all-butyrate scheme throughout on a fabric covered model. For sheet-covered models, or relatively fragile structures, the all-butyrate scheme, in fact may be superior because of the low tautening and minimum risk of warping, plus weight-saving through not needing a final coat of fuelproof.

Butyrate dopes, therefore, have their applications as finishes for glow engine powered models; and have achieved a position of equal, if not greater importance in the United States. Here the greater experience with these materials over a considerable number of years has enabled satisfactory formulations to be developed and fully proven.

There are, however, other finishes with a superior resistance to fuels, making the fuelproofing of non-resistant finishes a comparatively simple, and perfectly reliable process. Some of these new materials - such as polyurethane and epoxy - can also be used for through finishing, where no tautening action is required.

CHAPTER THREE

FUELPROOFERS

Fuelproofers are basically clear varnish-type coatings applied as a final coat over conventional finishes to render them impervious to the action of fuels. The primary requirements of a fuelproof, therefore, are that it should itself be completely resistant to attack by fuels, and also provide a complete and impervious 'skin' in a single coat. At the same time it must be compatible with the coatings over which it is applied.

Most fuel proofers are based on thermosetting resin 'skins', produced by the cold-curing of a suitable resin solution when mixed with a hardener. Single mixture solvent-type coatings are generally less suitable, unless the base material is itself fuelproof. Thus, cellulose dopes are, to a reasonable extent, resistant to diesel fuels, and butyrate dopes resistant to both diesel and glow fuels, but neither would be called a 'fuelproof', although butyrate compositions may be referred to as 'fuelproof' dope. A clear butyrate dope cannot be used as a fuelproof over a cellulose dope as there may be some interaction between the two, i.e. the two different materials (or their solvents) are not compatible.

Other solvent-type coatings which are resistant to diesel fuels and glow fuels, and can be used over conventional finishes, tend to have only limited resistance in the case of glow fuels, and particularly with increasing nitromethane content in these fuels. A high nitromethane content tends to make glow fuels much more active as solvents and so a requirement of a good all-purpose fuelproof is that it should have satisfactory resistance to high doped or so-called 'hot' glow fuels - specifically a resistance to attack by nitromethane as well as alcohol and castor oil. Only the two-part (thermosetting) resin coatings give this complete protection.

Whilst the formulation of such fuelproofers is fairly straightforward, there are other requirements which have to be met before the coating can be considered a satisfactory fuelproof for model work. It must not attack the original finish in any way, and it must also adhere to it strongly and uniformly. Quite a number of 'fuelproof' resins fail either by blistering or bubbling or otherwise yielding incomplete adhesion; or by crazing and cracking on hardening or after a period of ageing.

Even some proprietary fuelproofers are not entirely free from such faults, although these may occur only in individual cases. In the case of a finish over which considerable care has been taken it is, therefore, advisable to use only a fuelproofer which is known, from previous experience, to be satisfactory when used with such finishes - not to take a possible chance with a new and 'unproven' fuelproofer.

Probably the two best resins for fuelproofers are polyurethane and epoxy. The former, in particular, has been fully developed and exploited as a finishing medium both for clear coatings (varnishes) and colours (polyurethane paints). These are available in two types - two-part mixtures which produce complete thermoset characteristics; and one-shot or ordinary 'paint' mixtures which are obviously easier to apply. The former generally supply fully fuelproof coatings but not the same 'universal' adhesion to other coatings as the simple polyurethane mixtures.

Clear polyurethane varnishes of the two-part type give generally excellent fuelproof coatings with a minimum increase in weight, for they can be applied very thinly and still yield a homogeneous skin. Coloured polyurethane paints can also be used for finishing throughout, particularly if weight saving is not too important. Again two-part paints should be used.

Clear polyurethane sealer is also a very effective finish for bare wood, providing sealing and finishing to give a smooth, non-porous surface, plus a fuelproof 'skin'.

Finishes based on two-part epoxy resin mixtures are usually more expensive, but provide even harder and more resistant coatings than polyurethane. They are superior to polyurethane as fuelproofers, in the form of clear resins, but more susceptible to crazing and loss of adhesion because a straight epoxy resin is somewhat brittle and has low peel strength as an adhesive when thermoset. The coating can be made more flexible, and peel strength greatly improved, by modification of the resin (usually with synthetic rubber), but this may affect the resistance to attack by high nitro fuels. Epoxy resin type fuelproofers, therefore, are no simple answer to fuelproofing and require careful formulation if they are to provide entirely satisfactory results.

CHAPTER FOUR

PLASTIC ENAMELS AND PAINTS

Amongst the original types of paints and finishes, oil-bound paints and enamels generally have higher specific adhesion than cellulose paints. Oil-bound paints have largely been replaced by synthetic resin paints, using solvent-type carriers rather than oils, offering many advantages - notably better 'flow' properties, quicker drying times, higher gloss and more durable finishes. Synthetic resin paints are generally referred to as 'plastic paints'.

They - or their original oil-bound equivalents - are also the standard finish for plastic models, where the plastic is polystyrene (virtually the only plastic now used for injection moulded plastic kit production). Plastic paints for modelling (i.e. for painting plastic kits) differ slightly from general-purpose plastic paints in that even greater attention is given in formulation to produce good flow characteristics, making it easier to apply even coatings with absence of brush marks; resistance to sagging and reasonably fast drying times. Thus whilst ordinary household plastic paints, or oil-bound paints, could be used for finishing plastic models, they would not give such good results, as a general rule. Other types of paints could prove quite unsuitable. Thus cellulose finishes lack adhesion to polystyrene plastic, and also tend to attack the surface of the material. Emulsion paints lack adhesion, as do other water-soluble finishes.

For the finishing of plastic models, therefore, there is no reason to look farther than the plastic (model) paints which are widely available, and in the widest possible range of colours - virtually every colour needed for scale modelling, thus eliminating the need to mix up special colours or shades.

Basically, such colours are available in two forms - gloss or matt. All resin paints naturally tend to have a shiny or glossy appearance when dry, and this can be enhanced by the addition of further resins, if necessary. In fact, it is far easier to make a gloss resin paint than a matt paint in the same basic material. The formulation must be adjusted to 'kill' the natural gloss in the latter case. A number of so-called matt paints, in fact, are not true matt but still retain a slight gloss, which can be a disadvantage in scale model applications. For a critical application it is as well to check that a particular matt paint is true matt by trying it out first on a piece of scrap 'tree' material.

Gloss can be removed from a high gloss finish by rubbing down the surface with an abrasive. However, this can be a tedious and lengthy process, and not easily adapted to small components. Basically this process merely removed the outer surface of resin to expose the underlying layer of matt pigment and filler powders held by the binder. Such a surface is slightly absorbent and in a ready condition to take a 'polish', even from the imprint of a greasy finger. The general rule when a matt finish is required on a plastic model, then is to use a true matt paint. There are many such plastic paints available, although the colour range may not be so large as with gloss paints.

One great advantage offered by plastic (model) paints is that specialist paint manufacturers have gone to enormous trouble to duplicate as faithfully as possible true 'scale' colours for all types and ages of models - e.g. from World War I aircraft onwards. All plastic (model) paints, too, are formulated for brush application as this is obviously the way in which the majority of such paints will be applied. They are equally suitable for spray application when thinned down. Spraying is recommended as the best method of painting for all types of models, and the only suitable method for exhibition standard finishes, provided suitable high pressure spray equipment is available.

Spray application is made easy with paints and finishes

sold in aerosol cans. However, the use of aerosol paints is recommended for general painting only since it is difficult to get consistent, even coatings - and particularly to avoid sags and runs. Aerosol spray paints, and all low pressure spraygun systems, are quite unsuitable for high class finishing work. They may, however, be quite suitable for functional model finishes. Even clear dope, for example, is better sprayed on than brushed on.

CHAPTER FIVE

FILMS

Plastic films, such as cellophane, have been tried over the years as covering materials for model aircraft, with virtually no success. About ten years ago, however, a new type of polyester film was produced, called 'Melinex' which had the main property required of an all-in-one covering material - an ability to be tautened once applied to a frame.

This was done by the film being 'plane oriented' during manufacture. At the second stage of manufacture the film is heated to about 80 degrees C, when it becomes quite soft, and then stretched equally in two directions at right angles. It retains this new size on cooling down, the treatment also removing any brittleness from the film and improving its mechanical properties. More important still, if the film is subsequently heated to a similar temperature again, with the edges of any area fastened, it will tend to revert to its original size. If heated to a higher temperature (about 200 degrees C) it will not only contract or tauten, but undergo a change in composition that will stabilise it in that tautened condition.

Such a film obviously has considerable possibilities as a covering material for model aircraft. The high strength of Melinex (approximately 25,000 pounds per square inch, tensile) means that a very thin film can be used and still be stronger than tissue for lightweight covering. Also no conventional finishes need to be applied to tauten or proof the covering

There are, however, certain disadvantages. Firstly, the question of a suitable adhesive, which needs to provide specific adhesion because the film is non-porous. Rubber-base adhesives have been found to be most suitable, such as Evostik, Titebond 22 or 24, Bostik 1320, 1767, 1968 or 1775 and Pliobond 20 or 30.

The second disadvantage is that the film is elastic rather than rigid like doped tissue. This gives it a tendency to sag between supports in open frameworks and also means that the application of the film adds no rigidity to the frame. Sagging can be eliminated by using the film as a covering over a tautened tissue covering, when it becomes in effect a 'finish' surface treatment. It is far more difficult to apply in this way, because of the nature of the adhesives which have to be used, than conventional finishes for tissue covering. Also there is not necessarily any saving in weight. To use 'Melinex' as a minimum weight covering material and finish, therefore, it must be applied over frames which are rigid enough to start with, and with restricted open areas so that sagging is not a serious problem.

'Melinex', therefore, has limited applications as a light-weight covering and finish for model aircraft, but it is nevertheless a practical material for such jobs. It is available in sheet thicknesses from 0.00025" up to 0.005".

The next big step came when it was found that a polyester film could be satisfactorily coated with a heat-activated adhesive layer, so that a complete panel could be laid in place and attached by ironing. The heat of the iron both activates the adhesive, to produce bonding of the film to the surface underneath, and shrinking to tauten. The basic technique developed was to iron the film down around the outline first to secure it in place. Lighter ironing could then be applied over the remainder of the surface, to produce simultaneous bonding and tautening. This technique is applied to all such films, adequate heat being provided by a domestic electric iron of small size, such as a travelling iron.

One further development took place before films of this type were introduced commercially as model coverings. This was the addition of colour to the basic polyester film which is transparent. Rather than try to introduce colour in the film itself, it was found more satisfactory to apply colour to the back or 'inside' of the film as a surface layer, followed by the film. In this way it was possible to produce really solid, opaque

colours, with the film itself remaining on the outside and without modified properties, so that it retained its full strength and generally excellent resistance to solvents, etc. The only disadvantages are the fact that the total weight of the three-layer film is increased quite substantially, and also its cost. Nevertheless the advantages of having a covering material with a built-in finish, fully fuelproofed and with a high gloss surface are obvious, not the least being the time saving in use. In point of fact, too, both weight and cost also work out quite favourably compared with obtaining a similar quality finish on doped nylon covering, whilst its strength, and particularly impact strength, is better than that of nylon.

Such materials still have certain limitations. They are still basically 'elastic' films and so do not add rigidity like conventional doped covering materials. This is no disadvantage over sheeted surfaces, but for covering open areas it is generally recommended that the framework be tissue covered first and the film covering laid over this.

Whilst the basic technique of application is simple and straightforward, individual problems can arise, such as the best method of 'moulding' the film under the action of the iron to conform to compound curves, and the complete elimination of wrinkles and air bubbles. The latter can be a problem when covering sheeted areas, unless solvent can readily be absorbed into the structure underneath rather than be trapped between the surface and the film. Also excessive local heating can cause the colour layer to run, streak or smear. Practice is, therefore, needed to get the best results with such films so that any limitations present can be overcome by experience.

Preparation of a surface for taking the film requires basically, that all the surfaces on which the film will rest, and subsequently adhere to, be finished as smooth as possible and free from defects. Straightforward sanding is usually adequate. Sealing or grain filling is not normally necessary as the film adhesives do not have a 'lifting' effect on wood grains. Sanded surfaces must, however, be completely clean and free from dust before applying the film, as otherwise dust particles trapped

under the film will show up as lumps in the high gloss covering.

The first proprietary film of this type was 'Monokote' introduced in America by Topflite. This is now known as 'Standard Monokote'. A later, slightly modified film, with better mouldability as regards compound curves and somewhat lighter weight is known as 'Super Monokote'. Both types are available in this country. The British counterpart is 'Solarfilm' - a rather lighter film with a different type of adhesive, and more like 'Super Monokote' in mouldability than 'Monokote'.

Other proprietary films include 'Cover-rite', introduced by Sterling in the USA; and Graupner Polyester-Bespannfolie marketed in Germany and Continental Europe only.

The success of such films with built-in finish and heat-activated adhesive is undoubted. They have become an accepted alternative to standard covering and finishing techniques, particularly for the larger free flight or radio control models which are normally nylon covered and for control line models. Film materials of this type are not yet generally suitable for lightweight rubber and glider models (or any small model where weight saving is important). Single polyester films (e.g. 'Melinex') continue to find limited application in these fields, however.

CHAPTER SIX

EPOXY RESIN FINISHES

Epoxy resin compounds are produced in various forms for modelling use, both as 'fillers' and finishes (as well as adhesives, of course). They are relatively expensive materials to buy, but not necessarily uneconomic in use since a little goes a long way. Their great advantage is that they are capable of producing superior results with less effort, and a minimum of added weight.

For filling, epoxy compounds are usually rendered in the form of a trowelling cement, which can be thick or thin in consistency, depending on the way it is made up. It is best applied literally by trowelling onto the wood surface, using a stiff bladed palette knife or a similar tool, with an action similar to that of buttering bread.

This is an easy technique, the main limitation being that the material once mixed up has a limited pot life, and so must be used up during this period. Until experience is gained in the pot life available from a typical mix, only small amounts of epoxy should be mixed up at one time. Working can be continued on the trowelled surface whilst the epoxy is still relatively soft. This can be a considerable advantage in minimising the subsequent flattening down required to produce a dead smooth surface.

The epoxy trowelling coat sets very hard - so hard, in fact, that it is almost impossible to sand effectively with ordinary glasspaper. The more obvious rough spots are best removed with a metal file, whilst general flattening can be attempted with aluminium oxide or similar 'hard' abrasive paper. Final flattening should then be done with 150 or 180 grit wet-or-dry abrasive paper, used wet, followed by a 'buffing' coat with 320 grit abrasive to produce a glass smooth surface.

For some work, the trowelling cement can be thinned right down and applied by brush. This will not produce the same tough skin coating, unless several coats are applied sanding down between each. Some modellers prefer this technique, using the epoxy compound thinned to brushing consistency, although the completed job generally takes longer. Epoxy compound thinned to brushing consistency can also be used to touch up, or fill in, bare wood areas which might be exposed through over-energetic working on a trowelled coating.

Epoxy trowelling cement is strong enough to be used to form fillets and other shapes. The fillet shape can be roughly formed by trowelling the compound in position, smoothing as far as possible and then leaving to set. Final shaping can then be done with round files and scraping, finishing off with fine abrasive paper wrapped round dowels (preferably wet-or-dry type, used wet).

Epoxy resin compounds are also excellent media for applying reinforcement material, e.g. gauze bandage strips, or glass fibre or nylon sheeting (the former primarily used as local reinforcement for nose areas on aircraft fuselages, and nylon sheeting as an overall strengthening covering for model boat hulls). Trowelling cement can be used for this purpose, well thinned out, so as to make it easy to 'wet' the reinforcement material thoroughly. A final overall coating of epoxy can be applied when the original layer is almost set to provide a base for a perfectly smooth rather than a textured surface finish.

Epoxy resins are, of course, also suitable for use for glass fibre mouldings as an alternative to polyester, with substantial savings in weight. They are, however, more expensive than polyester resins used in this way. Further developments are taking place in this field, notably the appearance of 'light-weight' resins which can almost halve the weight of glass fibre mouldings for the same strength as the usual polyester GRP technique.

Epoxy Paints

Epoxy paints or finishes are a logical type to use over an epoxy-filled surface and are amongst the most durable of all finishes, yielding a glasslike appearance over a properly prepared surface. Epoxy finishes are fully resistant to fuels and most solvents, and relatively light in weight. Good covering is also obtained with a minimum of coats, over a suitable 'filled' surface. Epoxy paints also have a filling or sealing action, capable of filling small defects in the surface.

For best adhesion, epoxy resin paints are best applied over slight roughened surfaces i.e. not glass smooth or burnished but the type of surface finish produced by flattening with 320 or 400 grit abrasive. Best results are invariably achieved by spray application. Brush application usually produces unevenness, which is difficult to flat down completely even by final sanding and burnishing and polishing to restore the gloss. Spraying also reduces the drying time of epoxy paints, from approximately 24 hours to a matter of a few hours only, although actual drying time will depend on the temperature. The higher the temperature, the quicker the drying time. In no case should epoxy paints be applied at a temperature below about 50 degrees F, as otherwise drying time may be unduly prolonged.

A point often overlooked in applying a high gloss finish is that even the smallest surface imperfections will tend to show up in an exaggerated manner. Quite apart from the fact that a perfect finish will only be obtained over a perfectly prepared surface, dust can be a hazard when painting. The whole surface of the model should be vacuum cleaned if possible, and further wiped over with a tack rag immediately prior to painting. Painting should be done in a dust free atmosphere, and the model left in a dust free atmosphere to dry off.

Epoxy resin finishes are available in both clear (transparent) and colours. It is a general characteristic that the lighter colours tend to lack 'body' and thus may need several coats to produce a good, opaque overall colour rendering. This offsets one of the inherent advantages of epoxy resin finishes that a good film coating can be achieved with a minimum

number of coats (sometimes only a single coat). One way of getting round this with lighter colours is to apply a base coat of silver and then the lighter colours. The silver coat seems to make up for the lack of 'body' in the final colour coat(s).

CHAPTER SEVEN

COVERING AND FINISHING WEIGHTS

The lightest covering materials do not necessarily result in the lowest finished covering weight. This is because some covering materials are more 'open' or porous than others, and so need a greater proportion of dope to 'proof' or render properly sealed. Lightweight Modelspan, for example, is a lighter covering material than Jap tissue, but gives a higher covering weight - e.g. see Table I.

The type of finish used, and the method of finishing, thus has an important bearing on the true covering weight. The required finishing schedule is also governed by the covering material used, and the type and purpose of the model. Both are, to some extent, open to either selection or control.

Bare covering weight can be estimated in terms of the likely area of covering required and the specific weight of the material used. The easiest way is to relate covering area to wing area (which is usually a known figure for the model, or

TABLE I.
TYPICAL DOPED COVERING WEIGHTS
(Weight in ounces per 100 sq. in. area)

COVERING MATERIAL	COVERING COAT	CLEAR DOPE FINISHING			
		1	2	3	4
		COAT	COAT	COAT	COAT
Jap Tissue	.028	.0315	.034	.0375	.041
Heavy White Tissue	.0535	.0585	.0625	.0675	.072
Lightweight Modelspan	.0264	.0382	.053	.067	.082
Heavyweight Modelspan	.055	.070	.089	.104	.125
Lightweight Silk	.05 - .15	Dependant upon dope used and amount needed to tauten and fill			
Nylon	.10 - .20				

can readily be calculated). In the case of an orthodox cabin monoplane design, covering area or surface area of the fuselage will be almost the same as that of the wings, whilst the tail group can be estimated as having about one half the wing surface area. The total area of covering required then works out as:

$$(2 + 2 + 1) \times \text{wing area,} \\ \text{or 5 times the wing area.}$$

Typical figures for other types of models can be estimated from Table II.

TABLE II
TYPICAL COVERING SURFACE AREAS
(FACTOR = NO. OF TIMES ACTUAL WING AREA)

TYPE OF MODEL		WINGS	FUSELAGE	TAIL GROUP	TOTAL
Glider	- Semi-Scale	2	1.5 to 2	.5 to 1	4 to 5
	- Contest Type	2	.5 to 1	.35 to .5	2.85 to 3.5
Rubber	- Cabin	2	2	1	5
	- Stick	2	1	1	4
	- Contest	2	2	1	5
Power	- Cabin	2	2	1	5
	- Pylon	2	1.25	1	4.25
Control Car	- Sports	2	1 to 1.5	-	3 to 3.5
	- Stunt	2	1 to 1.5	-	3 to 3.5
Radio Control	- Sports	2	2	.5	4.5
	- Aerobatic	2	2	.35 to .5	4.35 to 4.5
Scale Model Types		2	1.5	.5	4

Typical finished weights can then be estimated on the basis of the finishing scheme employed. Such estimates can work out quite closely in the case of clear dope finishes applied over tissue coverings. Weights of doped silk or nylon coverings are more difficult to estimate because of the different absorption of such materials, even with similar dry weights. In the case of more elaborate finishing schemes, too, more attention is given to obtaining the required standard of finish than the actual number of coats of dope used. Coloured dopes may also be used, which are appreciably heavier than clear dopes. Also the weight of coloured dopes varies to some extent with the colour, aluminium or black generally being the lightest, and white the heaviest - see Table III.

TABLE III
COLOURED DOPES IN ORDER OF INCREASING WEIGHT

BLACK	(nigrocine dye)
ALUMINIUM	
BLACK	(dope)
DARK COLOURS	(e.g. dark blue, etc.)
RED	
ORANGE	
GREEN	
YELLOW	
LIGHT COLOURS	(e.g. light blue, etc.)
WHITE	

In a good many cases, the increase in weight where an exhibition standard finish is aimed at may be surprisingly high - as much as 3 ounces per 100 sq. in. or considerably greater than the weight of the basic covering material itself, (which would normally be silk, or preferably nylon, in such cases). Pre-coloured film coatings, in fact, are usually lighter than colour dope finishes of comparable high gloss standard, although the bare material weight is considerably higher.

Material weight in the case of the heavier covering materials is generally quoted in terms of ounces per square

yard. The weight of Jap silk can range from as little as 0.5 ounces per square yard up to 2 ounces per square yard, or from about 0.04 to 0.15 ounces per 100 square inches. Silks less than about 0.10 ounces per 100 square inches are very open weave and take a considerable amount of dope to fill, thus they do not necessarily represent any overall weight saving. Also, the more coats of dope used with silk, the more brittle the covering tends to become. The same is true to some extent of nylon, but nylon is generally a superior 'strong' covering material.

A typical weight for nylon covering material is 2 ounces per square yard (0.155 ounces per 100 sq. in.). Lighter weight nylons are available (taking more dope to fill, but not so much as ultra-lightweight silks); also heavier nylons up to about 4 ounces per square yard (0.31 ounces per 100 sq. in.). The actual weight of nylon selected is worth checking in critical applications. The '2 ounce' weight is suitable for most covering jobs.

Film weights, by contrast range from about 0.18 to 0.25 ounces per 100 sq. in., depending to some extent on the colour. This, of course, includes the weight of the 'finish' and the adhesive. Very much lighter covering films are available, but these have a far more limited application - See Chapter 5.

Various finishing schemes recommended for different types of models are summarised in the accompanying Tables. From these it should be possible to make fairly close estimates of likely 'covering and finishing' weights for suitable, or alternative schemes. For the aeromodeller builder/designer who is weight conscious and endeavours to incorporate weight control, as an important part of any new design or model, it is strongly recommended that records be kept of actual weights achieved with various models, comparing bare frame weights and finished weights. These will not only provide more accurate data than estimates, but also 'adjust' figures to the actual technique employed by the individual builder in the application of coverings and finishes.

Weight control is, however, considered of less importance

these days of more restrictive model specifications for contest work. It is, however, still important on all types of duration models and high performance free flight models. Also, without some measure of weight control, or keeping an eye on the build-up of weights, covering and finishing can add an excessive amount of weight which can only detract from the performance of the model in some way or other - even if it only means that it glides faster and lands more heavily.

CHAPTER EIGHT

METAL FINISHES

True metal finishes are a practical proposition on all types of model aircraft - and also other types of models, if desired. The medium used is invariably very thin aluminium sheet, either in the form of aluminium foil or thin metallised papers. The latter is generally easier to use since it can be bonded more readily to the surface to be covered, and can also be formed to duo-curves to some extent by rubbing in place without wrinkling or creasing.

The main limitation of aluminium foil and aluminised papers is that they wrinkle readily. Whilst panels can be smoothed out perfectly flat prior to application they will follow any surface irregularity or sag in the surface being covered. For this reason they produce a very unattractive slack-looking finish applied over open framework. Their use is thus virtually limited to covering over smooth 'solid' surfaces, such as sheet covering, if a realistic result is required. They can be applied over dope tissue covered frames or open structures, but the overall effect is then an irregular 'quilted' appearance. Theoretically, at least, it should be possible with aluminium foil to apply this to frameworks in a warm (and thus expanded) state, to tauten up on subsequent cooling, but this technique does not work out satisfactorily in practice.

Presenting a highly polished 'mirror' surface, aluminium foil or aluminised paper will show up clearly the slightest surface imperfections. Even applied over a 'solid' surface, therefore, the regularity of the covering will only be as good as the underlying surface finish. It cannot be better, and it will not bridge cracks or other surface defects. Balsa surfaces, therefore, should be prepared with the same care as for high gloss paint

finishing, with adequate sealer and filler coats so that any grain completely disappears and a dead smooth surface is produced as a base for the metal covering.

Attacking the problem is not necessarily a difficult job, obviously the covering job must be planned in logically sized 'panels', taking into account the shape and changes in contours which may be involved; and also what would be logical panel joint positions on an aircraft. It is always best to use as large panels as possible, to reduce the number of panel joint lines to a minimum and simplify the whole covering job. In the case of scale models, detail lines, such as panel joints lines and even rivet lines, can be 'embossed' or 'engraved' on the metallised covering, as appropriate. Embossing implies working these detail lines on the reverse side of the material before the covering is applied. Engraving is done by working on the outer surface, this time preferably after the covering has been bonded in place. A piece of hard wood, or a very hard pencil, sharpened to a suitable point makes an excellent embossing or engraving tool for such a soft metal as aluminium foil or aluminised paper. The paper material can generally be worked more accurately, and with finer detail, than plain foil, which is another reason in favour of its choice.

Rubber-base adhesives are generally suitable for bonding aluminised paper or aluminium foil to balsa, doped coverings, and most plastic materials (e.g. for metallising a plastic kit model).

Latex-type gums are not generally suitable for they tend to continue soaking, both into the foil backing and the underlying surface in the case of balsa; and also will not stick to doped tissue or metallised surfaces. Thin rubber solutions and rubber cements are best, adhering to all surfaces, including lap joints made with the metallised covering. They are more easy to work with than 'contact' adhesives which permit of no adjustment of 'shuffling' of panels once laid in place.

The best technique, generally, is to coat both surfaces with thin adhesive - i.e. the surface to be covered and the back

of the metallised covering, already cut to shape, or slightly over-size. Rubber-adhesives may have some solvent action on cellulose dopes, however, which may cause smearing if a metal trim strip, for example, is attached over coloured dope. A coat of 'contact' adhesive on the metallised strip only may be best in such cases, making sure that there is no excess adhesive to be squeezed out at the edge when the strip is smoothed in position.

Both metallised paper and aluminium foil will normally have some crinkles in it. After a suitable panel size has been cut from the sheet material it should be laid on a piece of clean glass and 'polished' with a soft cloth or cotton wool, metal surface uppermost in the case of metallised paper. This will smooth out all crinkles and should give the whole panel a completely consistent mirror-like surface.

Where curves have to be negotiated, the panel should be laid in place dry and smoothed down over the surface. Rub and work over, as necessary, to form the panel to a matching curve. Adhesive can then be applied and the panel permanently fitted.

Where the material cannot be moulded into matching compound curves, 'dry' working can be continued, letting a crease develop at one (or more) point(s) necessary to complete the curvature. These creases should be worked carefully into straight or curved narrow lines. There is then the option of glueing up and cutting through the covering at the crease lines to remove the crease; or cutting the panel so that the area bounded by crease lines is removed, bonding in place and then cutting and fitting another panel to complete the covering.

With other compound shapes it may be more advisable to work in smaller sections of 'panels' to complete a satisfactory 'moulded' covering, with neat separation lines. There is no reason why edge joints should not be lapped over, although this does give a less realistic appearance.

Stains or smears produced by surplus rubber adhesive can readily be removed with solvent, such as benzine or acetone (depending on the type of adhesive). Remember, however, that

since rubber-base adhesives are softened or dissolved by many solvents, including fuels, unsealed joint lines can be a source of weakness on power models. It may be as well to seal this with a coating of proofer; or better still use an epoxy resin adhesive for completing all edge joints likely to be exposed to fuel spray. An alternative is to arrange joint lines in logical places to be covered by capping strips, moulded from narrow strips of foil or metallised paper - e.g. on wing and tail surface leading edges. These capping strips can then be bonded in place with epoxy resin adhesive.

A metallised covering, once applied, can be further worked on, providing care is taken not to accidentally indent or otherwise damage the surface. The engraving of detail lines etc. has already been mentioned. The reproduction of 'engine turning', employed as a finishing technique on engine cowlings on many older aircraft, is another possibility. In this case a suitable turning tool can be an abrasive tip cut from medium hard to hard rubber mounted on nothing more elaborate in the way of a power tool than the spindle of a small electric motor.

Metallised coverings need not add greatly to the overall weight of a model. A typical weight for metallised paper is about 0.2 ounces per 100 sq. in. which, allowing for the weight of adhesive necessary to fix, gives a total covering weight of about 0.25 ounces per 100 sq. inches, or very little more than that of coloured film coverings. It is also a complete finish, requiring no further coatings.

Lighter weight coverings can be produced using aluminium foil, although the thinner foils are more difficult to handle than metallised papers. The lightest gauge of aluminium sheet generally available is 38 swg, which has a weight of 0.059 ounces per 100 sq. in. Weights of aluminium foil are as follows:

Foil thickness inches	Weight - ounces per 100 sq. in.
.005	0.049
.004	0.039
.003	0.029
.002	0.0195
.001	0.0098

CHAPTER NINE

FINISHING WOOD

All of the woods used in model making are relatively porous and so finishing bare wood with a high gloss surface requires a several-part technique. The first stage required is to seal the surface to reduce or eliminate absorption of subsequent coatings, after which pores or imperfections in the continuity of the surface have to be filled so that the grain entirely disappears in a smooth, overall surface. For a superior finish it is then desirable to apply a base coating or primer with the object of rendering the surface free of flaws, and one which can be worked upon with abrasives without cutting through the bare wood. At the same time this surface provides the 'key' for the final coat(s) of gloss finish to adhere to. Even this may not be the end of the line. A gloss paint finish can usually be further improved in gloss and overall appearance by burnishing or polishing.

The technique is basically the same with all woods. Balsa, being the softest and most porous, needs more sealing and filling than denser woods. Also it is more easily accidentally damaged by working on, so that rather gentler handling is called for. The extent to which these various finishing stages are carried out also depends on the end result required. For a functional finish, several stages may be skimped, and the fact that the final finish is far from perfect, is regarded as not important. For an exhibition standard finish, however - equivalent to car showroom finishes - there are no short cuts and a lot of labour is involved, if conventional finishes are employed.

Sealing and Filling

A sealer is really a thin cement, applied to penetrate the pores of the wood and they dry out, leaving a solid content behind in the grain. This build-up of solid provides the sealing action necessary, although several coats may be needed to provide complete and satisfactory sealing, especially on balsa.

Ordinary clear dope is a good sealer for balsa, and most other woods. It should be noted, however, that such sealers provide mainly sealing, with little 'filling' action since they have very little body. A considerable number of coats would have to be applied to deposit enough solids to provide filling as well as sealing.

So-called sanding sealers developed for model use are basically sealers mixed with an inert solid powder, such as chalk. They work both as sealers and fillers, the solids content acting as the filler, held in place by the cementing action of the sealer.

Certain other substances are also suitable as sealer/fillers. Emulsion paint is an example. This is a good sealer-filler for balsa (and for hardboard) for quick results, but not generally used for good class work. Polyurethane sealer is another good sealer-filler, the filler in this case being the resin content of the sealer solution. Neither type provides such a good keying surface for subsequent finishing in cellulose finishes as cellulose sealers, however.

All sealers and sealer-fillers have a tendency to lift and roughen the original grain surface. This is particularly marked in the case of balsa. It is therefore, necessary to flatten off the surface between sealer coats with abrasive, continuing as necessary until a final stage is reached when all the grain has disappeared and the surface has a uniform overall smoothness. During this initial working, however, some surface imperfections will almost certainly show up, too deep to be removed by filling and sanding. These must be made good with a stopping compound or much thicker filler.

It goes without saying, of course, that the original surface should first be finished as smooth as possible by fine sanding, followed by an overall smoothing with garnet paper. Sealing and filling cannot cover up general imperfections, and excessive use of stopper to make good is undesirable. It takes far longer to treat imperfections by stopping than to eliminate all major imperfections by initial sanding, except where deeper indentations or scores may be involved. These would, of necessity, have to be stopped. There is, however, an alternative technique for working on relatively rough and imperfect surfaces, using a trowelling type cement filler - see Chapter 6.

Each individual sealing or sander/sealer coat should be left to dry and then sanded smooth with 5/0 garnet paper. If any coarser paper seems to be needed, then this is an indication that the original smoothing of the wood surface was inadequate. However, it may be necessary on soft balsa to use a coarser abrasive for flattening the first two or three coats, when 5/0 garnet should be satisfactory on further coats. Better results in the final stages may be realised with 220 grit wet-or-dry abrasive, used dry.

If the grain has not disappeared completely at this stage, a heavier filler can be used - generally known as a primer filler. This should be flattened with an abrasive paper no coarser than 5/0 garnet or 220 grit wet-or-dry. Primers would normally be used in addition to sealers or sealer-fillers on all first class work, in which case the number of sealer coats could be reduced. A minimum of three sealer coats and three primer coats should be satisfactory on most woods, although more of each may be needed on balsa.

No traces of grain should be apparent at this stage, and all surface imperfections should have disappeared under the combined treatment of fillers and stopper. Minor flaws may still remain, however. It is then necessary to decide whether these are best treated with stopper, or are sufficiently minute to be covered by the undercoat paint.

It is the undercoat which finally determines the quality

of the final gloss coating. One, two or three coats may be required, each coat flattened down thoroughly when dry with 320 to 400 grit wet-or-dry abrasive. Anything less than a perfect surface overall on completion of this stage will show up as imperfections in the final gloss coat. It is also necessary to let the final undercoat dry completely before attempting to apply the gloss finish. The latter requires to be fairly thin, which means a fairly high proportion of solvent, which can have a softening and penetrating action on an undercoat which is not fully dried out. This can lead to grain raising.

Opinions differ as to the colour of undercoat which should be used. Some authorities maintain that the colour of the undercoat should be the same, or similar, to that of the final coat. Others prefer to use a white undercoat under a coloured gloss finish as bringing out the true colour of the finish better. Still another recommendation is the use of a silver undercoat to bring out lighter finish colours to best advantage. It follows, of course, that whatever colour is used, all undercoats should be matt, not shiny. There are objections to the use of aluminium for an undercoat because of this, except in the case of epoxy paint finishes (see Chapter 6).

Some authorities will also argue that the final gloss paint can equally well be applied by brush as spray, provided the painter is skilled. In fact this is just not so. Provided a suitable spray gun is used (with an air pressure of at least 30 psi), and correct spraying technique, a spray finish will always be superior to the best of brush finishes. Also very few people can produce an even, overall finish by brushing. Spraying, in fact, is also to be preferred to the undercoat(s) as well as the final gloss coats.

As a rough rule, a minimum of three final coats of gloss paint should be considered necessary, applied thinly and completely uniformly. If the final surface is to be burnished, more coats can be applied to get a thicker build up, with less danger of rubbing right through when burnishing. Also leave ample time for the final coats to harden thoroughly before attempting burnishing.

Burnishing should be done with a soft cloth, such as mutton cloth, and metal polish, such as Brasso, or a fine burnishing compound. This is actually a cutting action as will be seen by the amount of colour, which is transferred to the cloth. Any appearance of minute scratch marks on the surface when burnishing indicates that you are using too coarse an abrasive.

A number of the modern car cleaning compounds provide an alternative to burnishing. Some of the so-called cleaner-polishers contain an abrasive as well as a wax, so both burnish and wax polish at the same time. The degree of actual burnishing produced can again be judged by the amount of colour which comes off on the cloth.

Alternatively, of course, a high gloss paint finish can simply be brought up by wax polishing, a straight automobile wax polish being suitable for this job.

Although the technique of obtaining a first class finish is fairly well established, the results obtained by different individuals following the same technique is often quite different. Modellers who tend to be perfectionists will regard the finish as a matter of extreme importance, and give the necessary attention, time and patience to the job to get satisfactory results. The greater majority do not achieve anything like the same standard, nor are they likely to, even with long practice, unless they accept the time and care necessary at each stage. By simplifying the technique they can, however, produce quite satisfactory 'functional' finishes, with an appearance that is satisfying to them, at least.

There is however, a short cut to obtaining a high gloss finish of 'exhibition' standards - the use of the recently developed plastic film coverings with built-in colour finish (see Chapter 5).

CHAPTER TEN

FINISHING EXPANDED POLYSTYRENE

Expanded polystyrene, now widely used as a 'core' material for solid wing construction (and to a more limited extent for fuselage mouldings and hull mouldings in commercial model productions), has a generally unattractive, inconsistent surface texture unless skin-toughened. The latter is a technique applicable only to mouldings where the surface layer is virtually re-melted and pressed in a mould to form a skin layer of harder plastic. Furthermore, expanded polystyrene is readily attacked and dissolved by many solvents, including alcohol (present in glow fuels), and to a lesser extent ether (present in diesel fuels).

Expanded polystyrene wings, etc., therefore normally require a finishing treatment, both to improve their surface appearance (and in many cases add strength as well) and to fuel-proof the surface. Ordinary dopes and finishes cannot be used for such purposes as these also will attack expanded polystyrene. Although the attack may be only slight in some cases, e.g. with cellulose finishes, these are still unsuitable as finishes since they will not adhere or 'key' to the surface.

Emulsion Paints

The simplest way of finishing an expanded polystyrene surface is by painting with ordinary emulsion paint. This is both a sealer for the surface, and also provides a fuelproof coating. At the same time it can provide a coloured coating simply by using a coloured emulsion paint.

One coat is generally sufficient to provide reasonably good but not complete filling. Some porous patches will usually be still apparent on the surface. A second coating will usually fill these, to give a uniform overall coating. The weight added may be appreciable, but by no means excessive for flying models. This method of treatment, however, adds no extra strength to the foam material.

Tissue Covering

This is the lightest method of surface finishing expanded polystyrene, using white or coloured tissue as preferred. Lightweight tissue or Jap tissue can be used on smaller wings and components, and heavyweight tissue on larger components.

Only a limited range of adhesives are suitable for attaching tissue covering, selected from the following range:-

- (i) Water-soluble pastes, e.g. water-soluble cellulose wall-paper paste, such as Polycell.
- (ii) Latex solutions (water soluble)
- (iii) Dextrin pastes (e.g. Bondfix or white 'office' paste)
- (iv) PVA

Of these, PVA is probably the best choice, particularly for covering large areas.

The tissue covered surface does not provide a fuelproof coating, and so additional finishing is required. Cellulose finishes can be applied over the tissue in the usual way, e.g. clear or coloured dopes; or butyrate dopes for proofing against glow fuels. Fuelproofing should not be applied directly over plain tissue covering as it will penetrate extensively and may have a solvent or softening action on the underlying plastic foam. This depends on the type of fuelproofing used, and the actual properties of the expanded polystyrene material. Some foams are more resistant to a wider range of solvents than others.

Tissue covering followed by doping will provide a lighter finish than emulsion painting. Also the tissue covering will improve the strength of the whole component.

Sheet Wood Covering

This is the standard method of covering larger wing cores, using either sheet balsa as the covering or thin wood veneer. Balsa would appear a logical choice because of its light weight and easy working properties. However, balsa is difficult to obtain in widths greater than 4 inches, which can call for several edge-to-edge joints on a large chord wing. Also balsa, unless specially selected for 'cut', is difficult to bed to the small radius curve necessary to cover a leading edge.

Wood veneers can be obtained quite readily in widths up to 12" or 14", or even greater; and also in large sheets if necessary. Being thin, they can also more readily be bent to leading edge curves, providing the veneer is not too brittle. A hardwood veneer, too, will also produce a tougher skin covering than balsa, and can even work out lighter than sheet balsa covering. A typical veneer covering 20 thou thick will weigh no more, and probably less, than 1/16" sheet balsa covering. For a very rough estimate, allow for veneer being about three times as heavy as sheet balsa of the same thickness. Thus for a similar weight of covering, select the veneer thickness as one third that of sheet balsa which would be considered adequate for the job.

Only adhesives which are water-soluble are suitable for glueing balsa or veneer coverings to the expanded polystyrene core. The choice usually lies between contact adhesives of this type, such as Styro-Bond or Copydex, PVA, or UF resin wood-working glue, such as Cascamite or Aerolite. Contact adhesives permit a quick covering job - both surfaces being coated with adhesive, allowed to dry and then brought into contact, when they immediately stick. This calls for accurate positioning, and there is no chance to shuffle the covering to adjust its position at all. Nor can it be peeled off and repositioned without tearing lumps out of the polystyrene. PVA and UF resins permit quite a bit of shuffling to be done, if necessary, but have a much longer drying time and the veneer or balsa sheeting

has to be clamped or held in place by wrapping with rubber strip, or similar means, until the adhesive has fully set.

Balsa or veneer covered expanded polystyrene wing cores are finished as for wood surfaces, i.e. they can be sanded smooth and then finished with paints or dopes in the usual way. Clear polyurethane is a good finish for veneers, for it can act as both a sealer and a finish giving a semi-matt or gloss finish, according to the number of coats, and is also fuelproof. Coloured finishes will, of course, add substantially more weight, using any type of finish. Probably the most effective - and certainly the quickest - method of obtaining a high gloss coloured finish on a veneered or balsa surfaced wing, is to apply self-coloured film material directly to the wood surface (see Chapter 5). Such materials cannot be applied directly to expanded polystyrene surfaces, however. Both the heat of ironing and the activated adhesive on the film will soften expanded polystyrene.

For best results it is recommended that film covering on expanded polystyrene wing cores be applied over balsa sheet covering rather than veneer. The latter is a less porous material and as a consequence trouble may be experienced with bubbling of solvent under the film when the adhesive is activated by heat, (balsa surfaces seem to absorb free solvent readily and eliminate bubbling). Film coverings can be applied over tissue covered expanded polystyrene surfaces, but this time there is some danger of local softening and deformation of the plastic when ironing the film down.

NOTES:

*Figures refer to proportions of clear tautening dope and thinners, i.e. 50/50 means equal parts of dope and thinners.

Ø Filler coats can be 50/50 or 40/60 clear dope; or 50/50 clear dope mixed with filler powder; or matt colour 'undercoat' dopes, according to the type and quality of finish required.

'Undercoat' or filler coats should be flattened with very fine abrasive between coats and before the application of the final colour dopes.

CLEAR dope refers to clear tautening dope.

GLIDER dope refers to a stronger clear tautening dope.

As a general rule, except for the first coat (particularly on silk or nylon covering), two or more coats of thinned dope are preferable to one coat of thicker dope. Any final colour dope finishes should be applied thin over a suitable filler or undercoat.

TO SAVE WEIGHT the use of coloured dopes should be avoided. Coloured covering material should be used with clear dopes throughout. The final coats of dope can incorporate a small proportion of coloured dope to improve the colour rendering.

A final overall coat of fuelproofer is not essential with diesel powered models, but should be regarded as essential with glow engine powered models, unless butyrate dopes are used throughout.

For glow engines using high-nitro fuels, a final coat of fuelproofer is absolutely essential, even if butyrate dopes are used.

COVERING & FINISHING SCHEDULES

MODEL TYPE	COMPONENT	COVERING	FIRST COAT DOPE	SUBSEQUENT COATS
Lightweight Rubber or Glider	Fuselage	Light Tissue	50/50* Clear	2 or 3 50/50 Clear
	Wings	Light Tissue	50/50* Clear	1 or 2 50/50 Clear
	Tail Group	Light Tissue	50/50* Clear	1 50/50 Clear
Larger Rubber or Glider	Fuselage	Heavy Tissue	50/50 Clear	3 or 4 50/50 Clear
	Wings	Heavy Tissue	50/50 Clear	2 or 3 50/50 Clear
	Tail Group	Light Tissue	50/50 Clear	1 50/50 Clear
Power (Small to Medium)	Fuselage	Heavy Tissue	Clear	3 or 4 50/50 Clear
	Wings	Heavy Tissue	50/50 Clear	2 50/50 Clear
	Tail Group	Light Tissue	50/50 Clear	2 50/50 Clear Final overall coat of fuelproofer
Power (Medium)	Fuselage	Heavy Tissue or Light Nylon	Clear	1 of 50/50 + 3 colour
	Wings	Heavy Tissue or Nylon	Glider Clear	2 of 50/50 + 3 colour 1 of 50/50 + 2 colour
	Tail Group	Heavy Tissue	Glider 50/50 Clear	2 of 50/50 + 2 colour 1 of 50/50 + 1 colour Final overall coat of fuelproofer
Power (Large)	Fuselage	Nylon	Glider	1 or 2 of Glyder plus filler Ø coats as required plus 1 or 2 final colour
	Wings	Nylon	Glider	1 Glider plus filler Ø coats as required plus 1 or 2 final colour
	Tail Group	Nylon or Heavy Tissue	Glider Clear	1 of Clear or 50/50 plus filler Ø coats as required plus 1 or 2 final colour 2 of 50/50 plus final colour Final overall coat of fuelproofer